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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 394

THE PREVENTION OF ICE FORMATION ON GASOLINE TANK VENTS

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Summary

This investigation was conducted in the refrigerated wind tunnel at the Langley Memorial Aeronautical Laboratory, Langley Field, Va., to determine a suitable method for preventing the formation of ice on the vents of airplane gasoline tanks.

Tests were made on a variety of vent forms arranged in a number of different orientations relative to the direction of the air stream. Both the size of the tube and its orientation were found to be of great importance. Small tubes, under equal circumstances, were found to freeze over far more rapidly than large ones. Tubes pointing downstream, or shielded in other ways, appear to be perfectly immune against this hazard. A tube 3/4 inch in diameter with the opening pointing downstream is finally recommended as being the safest choice of gas tank vent.

Introduction

There exists at the present time no standardization of the gasoline tank vents on airplanes. On the different types of airplanes, the size, position, and location of the vent pipes differ considerably and indicate that the designs were made more or less at random.

The prime function of all such vents is, of course, to maintain a pressure inside the tank approximately equal to that of the atmosphere. The vent should do this under all circumstances without loss of gasoline; it must not admit foreign matter into the tank; and it should not freeze up when the airplane is flown under ice-forming weather conditions. It is this last condition which is the principal concern of this report.

Reports have been received that trouble has been experienced due to freezing over of some types of gasoline tank vents during flight under ice-forming weather conditions.

Means of eliminating this hazard have been investigated at the Langley Memorial Aeronautical Laboratory, Langley Field, Va. The effects of shape, and direction relative to the air stream, of various sizes of tube vents now in use on airplanes, were studied in the refrigerated wind tunnel. The time required for a complete freezing over of the vent opening has been employed as the criterion for the performance.

Experience has shown that the most severe conditions of ice formation occur at temperatures slightly below the freezing point. A temperature of 28° F. was chosen for these tests as being fairly representative of the condition of most concern.

The effect of vent-tube direction on the gas tank pressure has been given due consideration.

Apparatus and Methods

The refrigerated wind tunnel used in conducting these tests has been described in an earlier report from this laboratory. (N.A.C.A. Technical Note No. 339.)

Inasmuch as the usual type of gas tank vent consists of some kind of a tube which projects into the air stream, various sizes, shapes, and relative positions of vents of this type were tested in the wind tunnel. The types of the tubes for tests are shown in the four diagrams of Figure 1: unprotected tubes, mounted in the position shown in Diagram 1; unprotected tubes with the open end cut at an angle, Diagram 2; a U-shaped tube in such a position that the open end was behind or in the "shadow" of the main tube arm, Diagram 3; an L-shaped tube with the open end facing downstream, Diagram 4.

The effect of tube size was studied employing only straight vertical tubes as shown in Figure 1, Diagram 1. The tube diameters tested were 1/8 inch, 3/16 inch, 1/4 inch, 5/16 inch, 3/8 inch, and 1/2 inch. The majority of the other tests were made on a 3/8-inch tube. (See Table I.)

The gas tank pressure was measured by orienting the open end of an L-shaped vent tube at various angles with respect to the air stream. A larger wind tunnel was employed to insure greater accuracy.

Results and Discussion

The time required for the vertical unprotected tubes of different diameters (fig. 1, Diagram 1) to freeze over so that their ends were completely plugged, is given in Table I and in graphical form. (Fig. 2.) This curve indicates that tubes of more than 3/4-inch diameter would not freeze over within any usual limit of exposure to ice-forming conditions. Photographs of each size of tube with the formation of ice which accumulated on it are given in Figures 3 to 8, inclusive. Each photograph shows a bulbous formation of ice over the end. It was only after such a formation had accumulated that the end of the tube usually became sealed. In the photograph of the 1/2-inch tube (fig. 8) it appears as if the tube were entirely closed, but in this case the growth of ice assumed a horn shape over the end of the tube, with the hole actually increasing in size as the formation progressed. In fact, it was noticed that the ends of the smaller tubes always froze over entirely, while in the case of the larger tubes the diameter of the opening became larger as the growth of it continued. The apparent transition from bulbous to bell-shaped formation occurs at a pipe size in the neighborhood of 1/2 inch diameter when the pipe is at right angles to the air stream.

In tests made with the end of the 3/8-inch tube cut at a 45° angle, it took only about eight minutes for the tube to freeze over when the opening faced into the air stream (fig. 9), and the tube did not freeze over at all when the opening was turned downstream. (Fig. 10.) Figure 11 shows a formation of loose snow and rime which formed on the same tube at a temperature of 25° F. This formation likewise did not cover the end of the tube; the rather characteristic bulbous formation is still apparent. This last test verifies that more severe conditions exist at temperatures nearer the freezing point.

Tests were also made on two different shapes with the open ends of the tubes somewhat shielded from the direct air stream. Tests made on a U-shaped tube oriented as shown in Diagram 3 (fig. 1) showed that this shadowed position prevented very effectively the formation of ice on the open end of the tube. (Fig. 12.) Tests made on an L-shaped tube placed as shown in Diagram 4 (fig. 1) showed that this shadowed position also prevented effectively the formation of ice on the open end of the tube. (Fig. 13.) This is very apparent from the photograph.

Results of a pressure survey made on the L-shaped tube, in which the pressure was measured with the tube placed at various angles with respect to the air stream, are given in Figure 14 and in Table II. A positive pressure equal to $1/2\ \rho\ V^2$ exists in a gas tank when the tube is faced directly into the wind. This positive pressure gradually diminishes to zero as the tube is turned toward an angle of approximately 63° with the air stream. A positive pressure would of course be desirable, but foreign matter would then enter the tube and ice would form rapidly over the end. As the angle is increased from 63°, a negative pressure develops which reaches a maximum at 95°. This maximum negative pressure is fairly high, being of the order of $-0.8\ \rho\ V^2$. (Fig. 14.) U-tubes with the openings facing down, which are in general use on most present wing tanks, are therefore somewhat undesirable because of high negative pressures. Increasing the angle of the tube beyond 95° reduces the negative pressure rapidly until at 180° it has a value of approximately only $-0.1\ \rho\ V^2$. Hence, the shape and position shown in Figure 1, Diagram 4, appears to be most suitable for gas tank vents. The pressure which exists in a gas tank with the tube in this position is a very acceptable figure.

A pressure measurement was also made with the tube at right angles to the air stream but with the end of the tube cut at an angle of 45° and with the opening facing downstream, as shown in Figure 1, Diagram 2. This arrangement gave a negative pressure which was considerably less than that obtained with the straight-end tube at right angles, being numerically less than $1/2\ \rho\ V^2$. (Table II.) Hence, if a vent tube placed at right angles to the air stream were used, it would be much better to cut the end at a 45° angle toward the back, inasmuch as this arrangement would also be satisfactory as regards ice formation. However, as previously mentioned, it is better still to use a straight-end tube facing directly downstream.

CONCLUSIONS

1. Tubes pointing downstream, or with the opening in any way shielded from the direct air stream, appear to be perfectly immune from the ice hazard.

2. With the tube perpendicular to the air stream, or with the end in any way exposed, the time required to freeze over increases greatly with the size.

3. The use of a 3/4-inch tube, bent at a right angle and placed with the open end pointing downstream, is recommended as being the safest arrangement for gasoline tank vents as regards the ice hazard, and also the most practicable with respect to the gas tank pressure.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 16, 1931

Table I

Ice Formation on Gasoline Tank Vents

Pipe diameter inches		Time to freeze minutes	Photograph	Condition
1/8	0.125	3	1 B (fig. 3)	Plain exposed pipe
3/16	.1875	5	4 A (fig. 4)	Plain exposed pipe
1/4	.25	7	3 A (fig. 5)	Plain exposed pipe
5/16	.312	10-1/2	2 A (fig. 6)	Plain exposed pipe
3/8	.375	18	1 A (fig. 7)	Plain exposed pipe
1/2	.5	Did not freeze	A O (fig. 8)	Plain exposed pipe
3/8	.375	Did not freeze	2 B (fig. 12)	Pipe turned down wind 15 min.
3/8	.375	8	3 B (fig. 9)	Angled to wind
3/8	.375	Did not freeze	4 B (fig. 10)	Angled against wind 15 min.
3/8	.375	Did not freeze	5 B (fig. 11)	Snow
5/16	.312	Did not freeze	6 B (fig. 13)	Pointed downstream

Table II

Pressure in Tube in Different Positions

Air velocity = 80 m.p.h.

Angle away from forward position degrees	Excess pressure cm of alcohol	Excess pressure $8 = 1/2\ \rho\ V^2$
0	+ 9.2	+1.0
45	+ 4.5	+0.49
80	-10.4	-1.13
90	-14.0	-1.52
95	-14.9	-1.62
100	-13.8	-1.5
135	-3.8	-0.413
180	-1.9	-0.206
90 (cut at 45° away from wind)	-8.0	-0.87

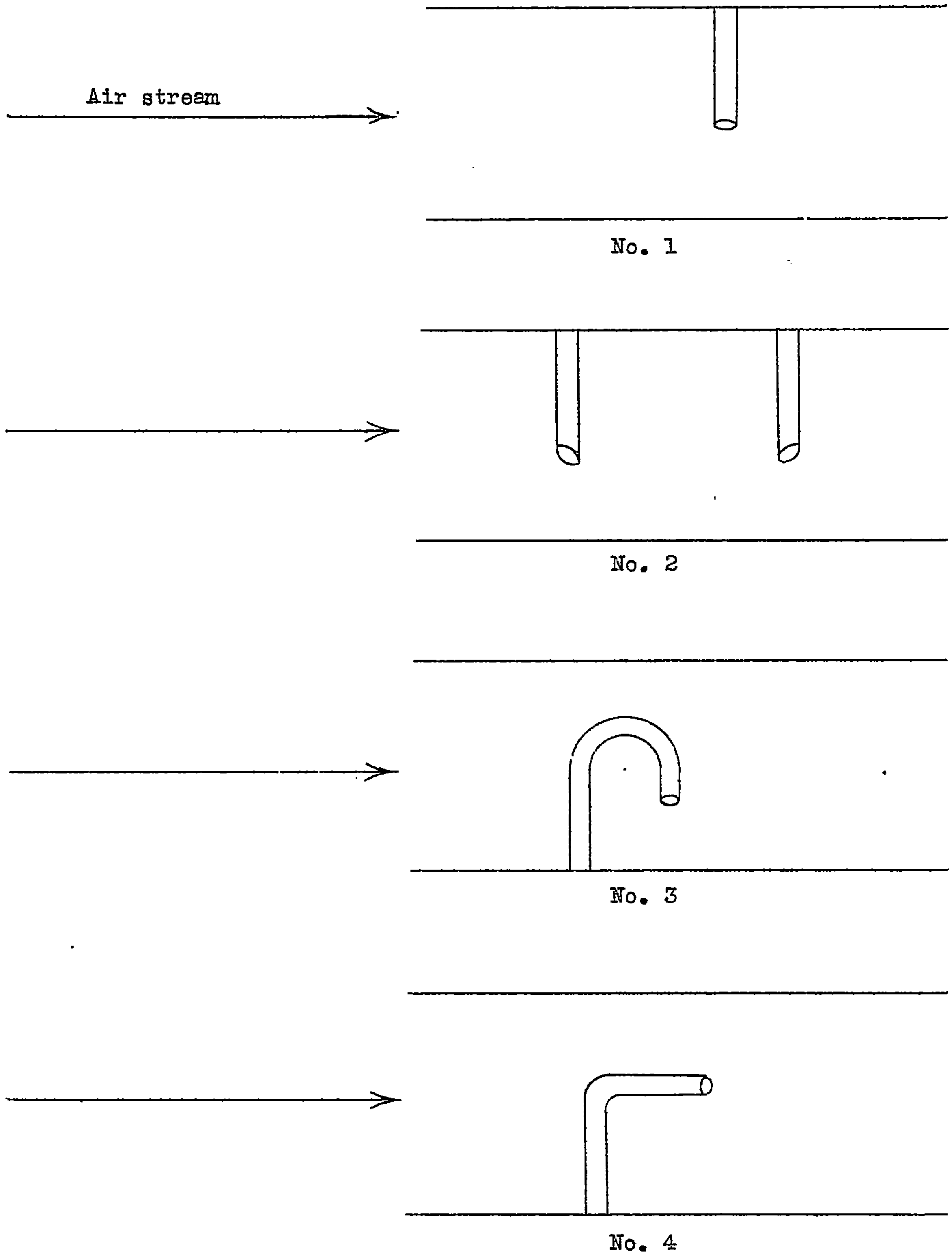


Fig. 1, Diagrams showing shape and position of tubes tested.

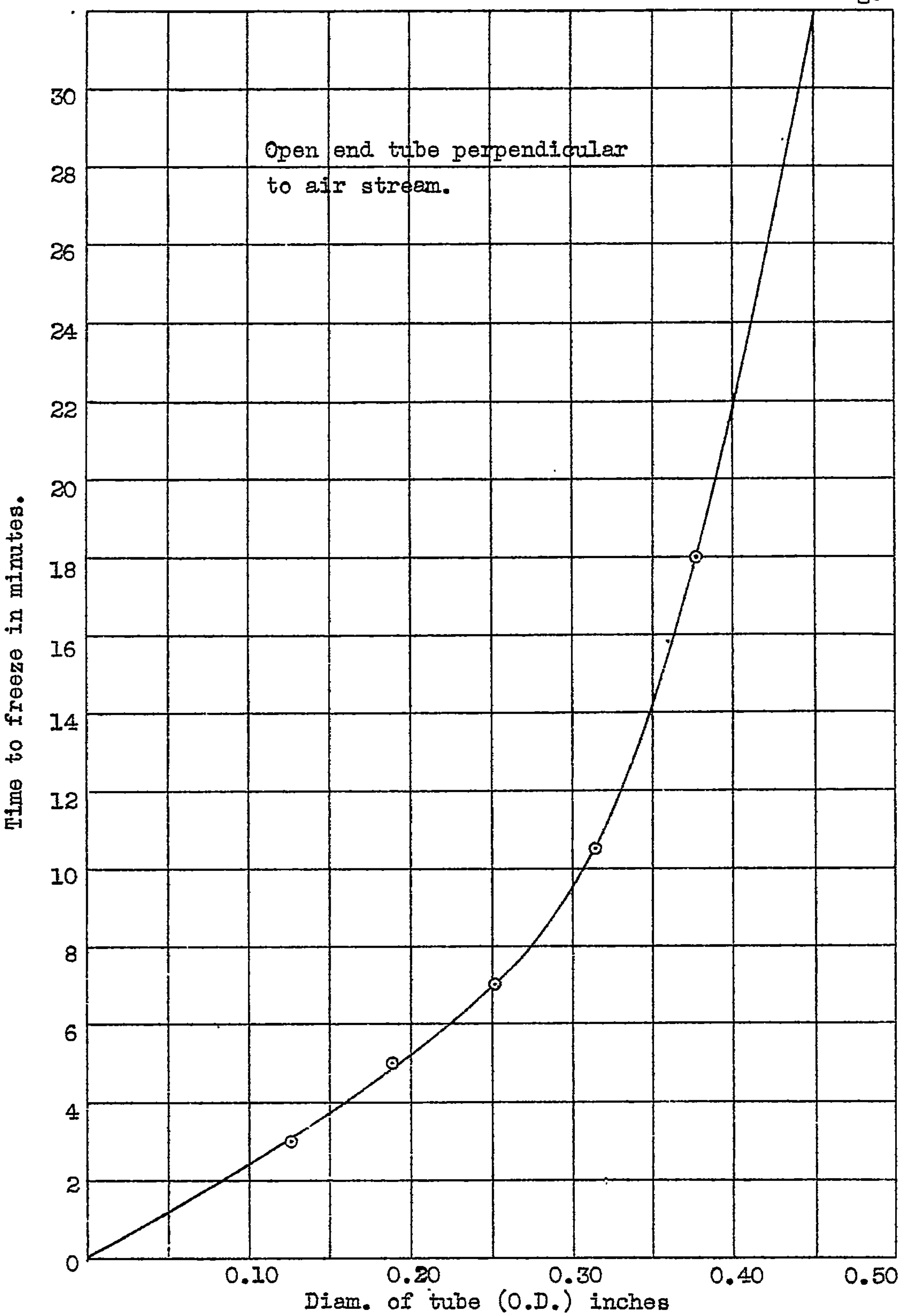


Fig. 2 Effect of tube size on time required to freeze over.

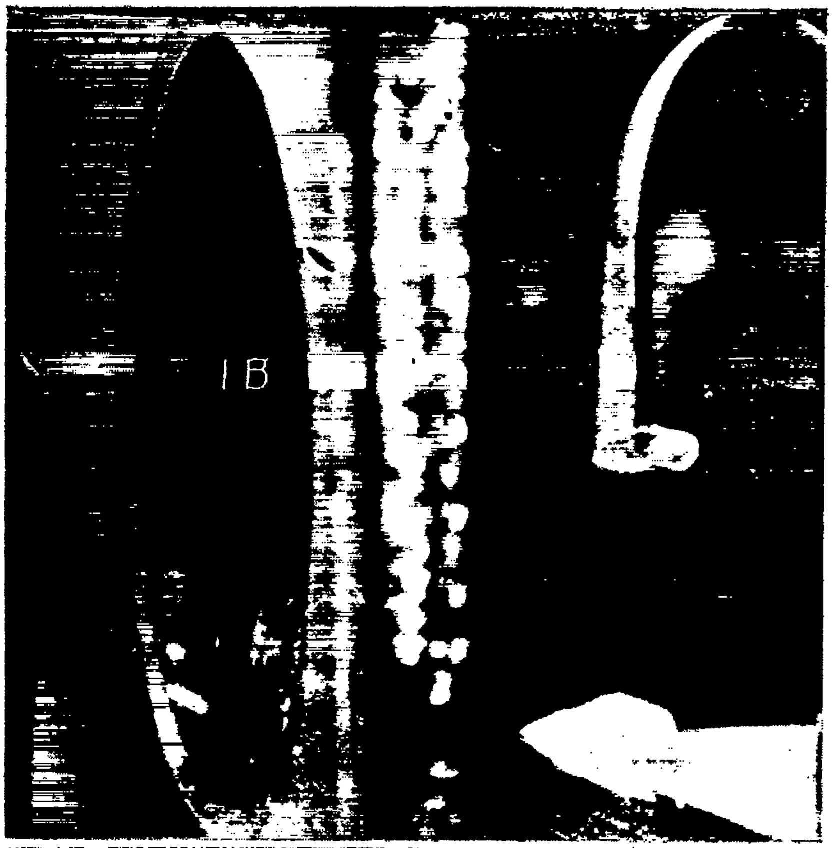


Fig. 3

Ice formation on exposed end of 1/8" tube. Tube froze over in 3 minutes. Air stream direction, left to right.

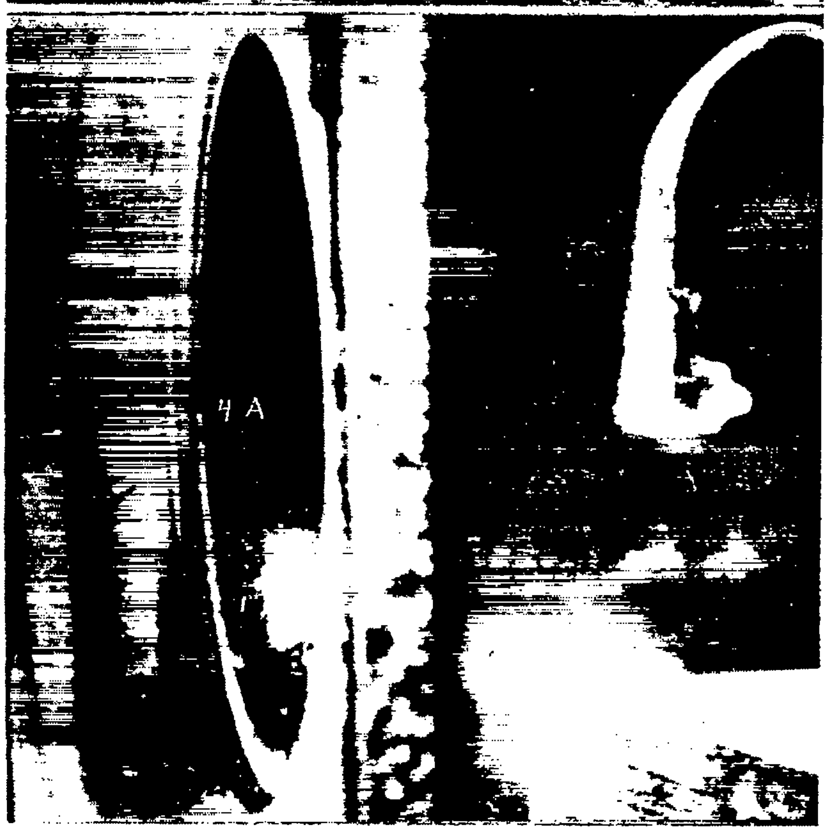


Fig. 4

Ice formation on exposed end of 3/16" tube. Tube froze over in 5 minutes. Air stream direction, left to right.

Fig. 5

Ice formation on exposed end of 1/4" tube. Tube froze over in 7 minutes. Air stream direction, left to right.

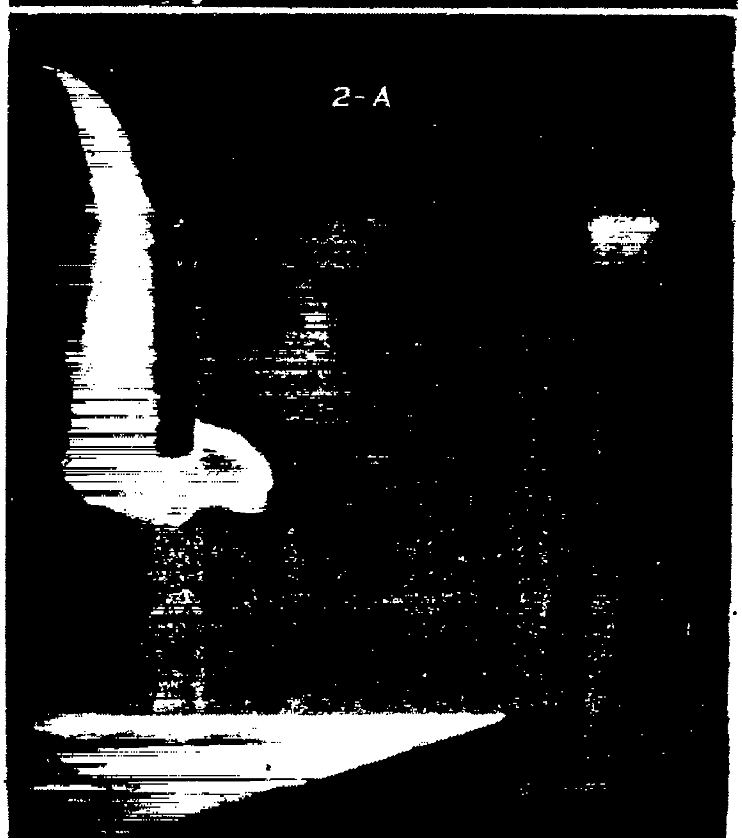


Fig. 6

Ice formation on exposed end of 5/16" tube. Tube froze over in 10-1/2 min. Air stream direction, left to right.

Fig. 7

Ice formation on exposed end of 3/8" tube. Tube froze over in 18 min. Air stream direction, left to right.

Fig. 8

Thirty-minute ice formation on exposed end of 1/2" tube. Tube is not frozen over. Air stream direction, left to right.

Fig. 9 Ice formation on exposed end of 3/8" tube with the end of the tube cut at an angle and facing the air stream. Tube froze over in 8 min. Air stream direction, left to right.

Fig. 10 Ice formation on exposed end of 3/8" tube with the end of the tube cut at an angle and facing downstream. Tube did not freeze over. Air stream direction, left to right.

Fig. 11 Snow and rime formation on 3/8" tube, angled and facing downstream. Tube did not freeze over. Air stream direction, left to right.

Fig. 12 Ice formation on protected end of U-tube. Tube did not freeze over. Air stream direction, left to right.

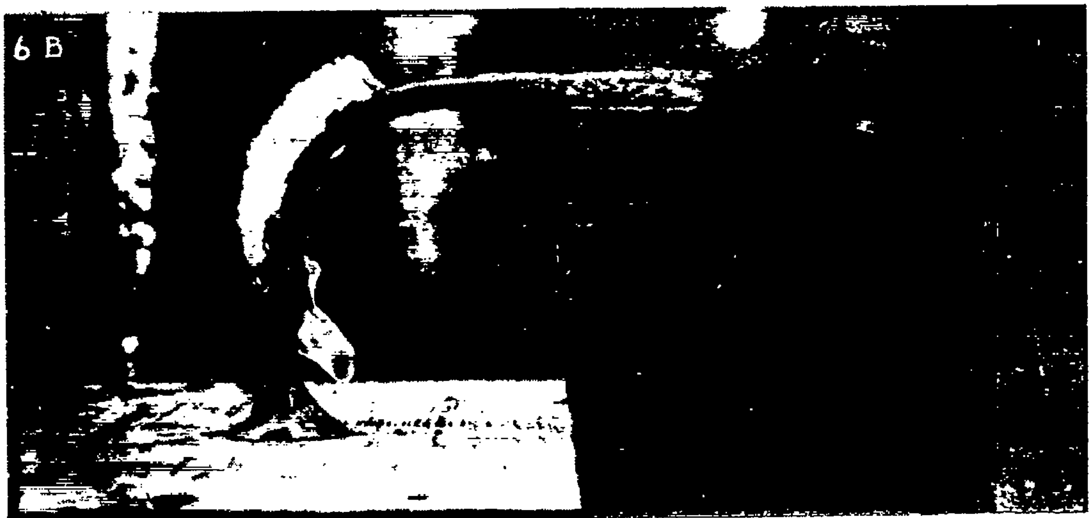
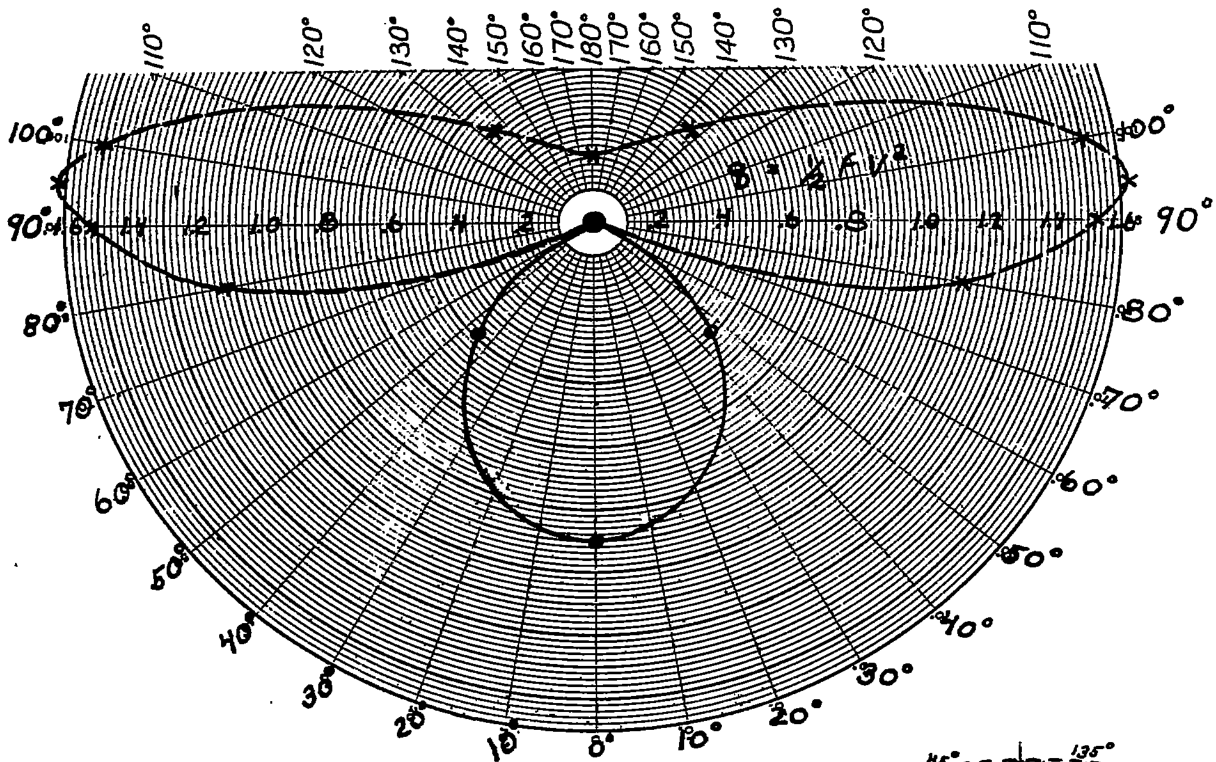


Fig. 13 Ice formation on protected end of L-tube. Tube did not freeze over.
Air stream direction, left to right.



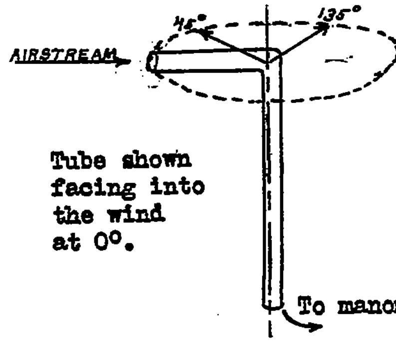


Fig. 14

Pressure head as function of angle

Tube shown facing into the wind at 0°.

To manometer